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AN
ACCOUNT
OF
EXPERIMENTS,
TO DETERMINE THE
SPECIFIC GRAVITIES OF FLUIDS,
THEREBY TO OBTAIN
The Strength of Spirituous Liquors.
TOGETHER WITH
SOME REMARKS ON A PAPER ENTITLED,
The Beſt Method of Proportioning the Exciſe upon Spirituous Liquors.
LATELY PRINTED IN THE PHILOSOPHICAL TRANSACTIONS.

BY J. RAMSDEN.

London:
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BRITISH MUSEUM

A N

ACCOUNT,

&c. &c.

IT appears, by a late paper, printed in the *Philoſophical Tranſactions* (vol. LXXX.), that government have it in contemplation to adopt new regulations for aſcertaining the duty on ſpirituous liquors; and for this purpoſe have applied to the PRESIDENT of the ROYAL SOCIETY, to conſider on a ſet of experiments to carry them into execution; and from thence to contrive a practical method, whereby the exciſe officer may be enabled to aſcertain the duties on the different compounds, which may come under his inſpection, in the moſt eaſy and ſatisfactory manner.

On peruſing the report made by the Secretary of the Royal Society on this ſubject, the plan purſued, in their experiments, appeared to me not quite ſo well adapted to the purpoſes for which they were made, as might have been expected.

Having, many years ago, paid ſome attention to this matter, I ſhall put together a few obſervations thereon, and communicate a *ſuite* of very ſimple experiments, whereby any one interested in theſe matters may, by an eaſy proceſs, and at a very trifling expence, obtain more ſatisfactory reſults than have been had hitherto. I ſhall alſo give a deſcription of an inſtrument for determining the Specific Gravity of any Compound conſiſting of ſpirit and of water; together with the quantity of ſpirit, of a given ſtrength, contained therein, in hundredth parts of its volume. Moreover, to enable us to aſcertain the proportion of ſpirit in the compound now called *Proof*, I ſhall give a practical method of obtaining a gallon-meaſure, with more preciſion than can be wanted for the purpoſes of commerce, or of revenue.

The ſubject divides itſelf into four Parts, namely:

1. The method of proportioning, and expreſſing in meaſures, the quantities of ſpirit in the compounds; and of determining the ſpecific gravities of the ſame.

2. A means of aſcertaining the increaſe, or diminution, in the bulk of a compound, ariſing from different degrees of temperature; with a deſcription of an inſtrument for that purpoſe.

3. The application of the experiments under the two preceding heads, to the conſtruction of an hydrometer, which will give the ſpecific gravity of any compound in thouſandth parts of that of diſtilled water, and, at the ſame time, the quantity of ſpirits, of a given ſtrength, in the compound, in hundredth parts of the volume.

4. A means of determining the proportion of ſpirits to water, in the compound now called *Proof;* which, by the Commiſſioners of the Cuſtoms, is ſtated to weigh 7℔ 12℥ *per* gallon, at the temperature of 55 degrees. It being requiſite, for this purpoſe, to have the exact gallon-meaſure, I ſhall give a practical method for aſcertaining that quantity, without an error amounting to $\frac{1}{10000}$ part of the whole.

To return to the firſt Part, I ſhall here relate the method I practiſed, for proportioning the quantity of ſpirit in a compound, about the year 1776; at which time I made hydrometers that gave the quantity of pure ſpirit, in hundredth parts of the meaſure of the compound.

I took a glaſs bottle of the form repreſented by *fig.* 1; the lower part B would contain about a pint and a half. The two cavities, A and B were connected by a ſmall neck, having a circle cut round it. After carefully weighing the bottle, I filled it with ſpirit till the circle appeared to an eye viewing it horizontally, as a tangent to the inverted curve on the ſurface of the ſpirit: again, weighing the bottle with its contents, I obtained the weight of the ſpirit it contained. This weight I conſidered as unity. Now the method of proportioning the different mixtures being only a repetition of the ſame proceſs, it will be ſufficient to deſcribe one only; I ſhall, therefore, take that containing $\frac{65}{100}$ or 65 *per cent.* by meaſure, of ſpirit in the compound.

After emptying the bottle, I returned into it $\frac{65}{100}$ of the quantity of ſpirit it had contained, filling the remaining part of the cavity with diſtilled water, till the ſurface of the fluid roſe to the circle above deſcribed on the neck of the bottle; and, after ſhaking well the compound, I left it, to give time for the two ſubſtances to penetrate each other. Whenever the compound was found to have contracted, by the ſurface thereof falling below the circle on the neck of the bottle, I filled it again to that point, with diſtilled water, and repeated this till it appeared to diminiſh no farther. Thus I obtained a mixture, containing $\frac{65}{100}$ parts of the volume of the compound of ſpirit, by a very ſimple experiment. This was preſerved in a cloſe-ſtopped bottle, prepared for the purpoſe, till all the different mixtures of ſpirit and of water, that I had occaſion for, were made: which being done, they were afterwards ſubjected to the experiments for obtaining their ſpecific gravities.

Having made the propoſed number of mixtures, to determine the ſpecific gravity of each, at a given degree of temperature, Take a bottle, about 2½ or 2 inches diameter, of the form repreſented by *fig.* 3. with a ſmall neck, about the diameter of 0, 3 inch; and let the ſurface or end of the neck be ground very flat and ſmooth; let there be a very ſenſible thermometer, with its ball juſt ſmall enough to paſs through the neck of the bottle: the tube of the thermometer ſhould be ground flat on one ſide, that the degrees may be marked thereon; and, in order to have thoſe degrees as large as poſſible, the whole length of the tube need not contain more than 10 or 12 degrees, from about 53 to 63; then take a ſmall circular plate of flat glaſs, its diameter being about the ſame as the outſide diameter of the neck of the bottle; let one of its ſurfaces be ground and poliſhed very flat, and make a hole through its centre juſt ſufficient to receive the end of the thermometer tube, which ſhould be ground into it till it ſticks very faſt; ſo that when the plate is laid on the ſurface of the neck of the bottle, the ball of the thermometer may deſcend almoſt to the bottom of it. Having weighed, or rather counterpoiſed the bottle, with its thermometer, in a very nice balance, fill it with diſtilled water about the ſame temperature as the room; then put the thermometer into the bottle—this will cauſe the water to run over the neck of it, and the plate of glaſs, falling on the ſurface of the water, will preſs off that part which had riſen above the neck: this done, and the counterpoiſe remaining in the ſcale, weigh the water, and obſerve the temperature ſhewn by the thermometer within the bottle: by this means we have the weight of the quantity of diſtilled water that filled the interior cavity; then empty the bottle, and drying it well, fill it with the compound that is to be the ſubject of the experiment; and again weighing the contents, obſerve its temperature, which I will ſuppoſe the ſame as the water, or 60 degrees. Now it is obvious, *the weight of diſtilled water, will be to the weight of the compound, as unity, is to its ſpecific gravity, at the above temperature.* Thus we have the ſpecific gravity of the compound, containing $\frac{65}{100}$ parts of its volume of ſpirit. And, by the ſame method, we may obtain the ſpecific gravity of each different mixture.

The object of the ſecond Part, is to aſcertain the quantity of expanſion, or contraction, of the mixture for different degrees of temperature; for which purpoſe I ſhall give the following deſcription of an inſtrument, whereby thoſe reſults may be obtained in 10,000th parts of the magnitude of the compound.

Take a glaſs veſſel, of the form repreſented by *fig.* 2. conſiſting of a glaſs bulb about 1¼ inch diameter, with a tube riſing from it ſimilar to that of a ſpirit-thermometer: the ball and tube being proportioned to each other in ſuch manner, that, when filled with ſpirit, and immerſed in ice, the ſurface of the ſpirit in the tube may ſink down nearly to the ball; and, when immerſed in water, at the temperature of about 100 degrees, the ſpirit may riſe nearly to the top of the tube. To enable us to fill this thermometer with any fluid, without applying heat, there is a ſhort tube, riſing from one ſide of the ball, that may be ſtopped with a very exact ground ſtopper for that purpoſe: after weighing the veſſel, while empty, pour into it a quantity of mercury, ſufficient to fill the ball and half the tube, and mark the tube at the ſurface of the mercury: again, weighing the glaſs, with its contents, we obtain the weight of a quantity of mercury, equal to the cavity of the ball, and the part of the tube that is below the mark.—Take another quantity, equal to $\frac{1}{100}$ part of the former, and, having poured it into the tube, mark it where the ſurface of the mercury now is: again, pour in another quantity, the ſame as before, and mark the tube again: this done, take out the two portions laſt put in, and $\frac{1}{100}$ part of the original quantity, and mark the tube at the ſurface of the mercury; and again, take out another part, equal to the laſt, and mark the ſurface. Now it is evident, that the ſpaces, or the interior cavity of the glaſs tube between each of thoſe marks, is equal to $\frac{1}{100}$ part of the volume of the mercury firſt put in the veſſel. Divide the ſpaces between each of thoſe marks into hundredth parts (having regard to the inequality of the interior caliber of the tube, if there ſhould be any), and the ſpaces between each of the diviſions will be equal to $\frac{1}{10000}$ part of the cavity occupied by the quantity of mercury firſt put in the veſſel. It would be convenient to have this inſtrument fitted on a ſcale of braſs or ivory, or other ſubſtance; and the diviſions above-mentioned graduated thereon, beginning with the diviſion at the ſurface of the quantity of mercury firſt put in; which diviſion mark 0, and number the diviſions above and below this point, at every 10th, with 10, 20, 30, &c.—The numbers above the zero expreſſing the quantity of expanſion in ten thouſandth parts of the volume, and thoſe below the zero, the contraction in ten thouſandths.*

To apply this inſtrument to practice, we have only to fill the ball and the tube to the diviſion 0, with the fluid that is to be the ſubject of the experiment, at a given temperature: for inſtance—at 60 degrees. The filling will be much facilitated by taking out the ſtopper, in order to let the air eſcape from the ball, which, on being filled, the ſtopper muſt be replaced: this done, immerge the inſtrument along with a very exact thermometer, in a large veſſel of water, heated to about 100 degrees, but in which the temperature changes ſlowly; and obſerve very accurately when the mercury in the thermometer deſcends to each degree on its ſcale; at the ſame time read off the diviſions ſhewn by the ſurface of the fluid on the ſcale of expanſion; theſe will expreſs the quantities of expanſion in ten thouſandth parts, for thoſe degrees of temperature. In like manner, obſerve the quantity of contraction when the temperature is below 60 degrees, or when the ſurface of the fluid in the inſtrument is below the zero on its ſcale.

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* In this proceſs I prefer mercury to a rarer fluid, becauſe the ſcale can be determined ſo much more correctly by one than the other, in the proportion of their denſities.

It may be eaſier in practice, if, inſtead of the ſtopper, the inſtrument be made with two tubes, riſing parallel to each other from the ball, as in *fig.* 4; ſo that when the fluid is poured into one of the tubes, the air from the ball may eſcape by the other. Every other part of the proceſs of making, and of uſing, being the ſame with what has been already deſcribed, it will be needleſs to repeat it;—only regard muſt be had to the interior calibers of both the tubes.

Thus, we have an inſtrument, the making of which I conſider more as the buſineſs of an inſtrument-maker than of a philoſopher, whereby we may obtain the contraction or expanſion of a fluid, in ten thouſandth parts of its volume, for each degree of the thermometer, by an eaſy proceſs; and thereby avoid many inconveniences attending the determination of expanſions by weight.

We come now to the third Part; under which I ſhall deſcribe the new *Balance Hydrometer*.

From the circumſtance of the ſtem of the common hydrometer always bearing the ſame proportion to the ſize of the bulb, it follows, that the ſpecific gravities determined by that inſtrument muſt be erroneous, and require a correction: this, together with the adheſion of the fluid to the ſtem, and alſo its being ſo exceedingly liable to accidents, induced me to think of conſtructing ſome inſtrument more ſimple, accurate, and not ſo ſubject to be out of order, as a ſubſtitute. With an inſtrument, ſuch as I am about to deſcribe, we may, with eaſe and certainty, obtain the ſpecific gravity of any fluid, to the exactneſs of $\frac{1}{6000}$ part of the whole. It has alſo this further advantage—that it precludes the uſe of two tables, both of which are indiſpenſibly neceſſary when the common hydrometer is uſed; one for correcting the errors ariſing from the ſtem—the other, for reducing the ſpecific gravity of a compound to *per cents*.

The mechaniſm of theſe inſtruments I have contrived different ways, ſome more convenient than others; but, to give an idea of the principle, I ſhall deſcribe that of the moſt ſimple conſtruction.

The *Balance Hydrometer* conſiſts of a braſs lever, about four inches long, that turns on an axis, repreſented by *fig.* 5.—At one end of the lever is a hook, to which a glaſs bulb is ſuſpended by means of an horſe-hair: the axis of the lever turns in holes in two ſupports; and, for the conveniency of detaching the lever and its axis from the holes (when occaſion may require), the two ſupports by preſſing a button, are made to ſpring open a little to give room for the axis to be diſengaged. On the lever is a ſliding piece, or weight, that may occaſionally be ſlid along the beam; and, on the beam or lever, are two ſcales; one ſhewing the ſpecific gravity of the fluid that is ſubjected to experiment; the other, the quantity of ſpirit contained in any given compound conſiſting of ſpirit and of water, in hundredth parts of the volume. The firſt of theſe ſcales contains 200 diviſions, the extreme one towards the hook being numbered 1000, the others at every 10th, with 990, 980, 970, &c. to 800: the other ſcale contains 100 diviſions only, and is numbered at every 10th diviſion, beginning at the end towards the hook, with 0, 10, 20, &c. to 100. The indices for theſe diviſions are on the ſliding piece.

The veſſel that contains the mixture may either be of glaſs or metal; and, for the conveniency of carriage, the fulcrum is made ſo that it may be ſlipt off the edge of the veſſel at pleaſure.

The application of the *Balance Hydrometer* to the determination of the ſpecific gravity of any fluid, is as follows:

Pour a ſufficient quantity of the fluid to be examined into the veſſel, and ſlip the fulcrum on the edge thereof; then laying the axis of the beam in the holes in the ſupports, immerge the glaſs bulb in the fluid that is in the veſſel, and ſlide the weight along the beam till the two ends are in equilibrum; the number of diviſions ſhewn by the index on the ſlider on one of the ſcales, will give the ſpecific gravity of the fluid in thouſandth parts: at the ſame time, the other index on the ſlider will give, on its proper ſcale, the quantity, or the proportion of ſpirit in any compound of ſpirit and of water, in hundredths of the volume, at the given degree of temperature.

It may not be amiſs to mention here, that the bulb, immerſed in the fluid, being of the ſame material with the veſſels in which the experiments for determining the expanſion and ſpecific gravities were made, no correction is neceſſary on account of the expanſion of thoſe veſſels by heat: but when materials are uſed that have different expanſions, the reſults muſt be corrected by the difference between the quantities of expanſion of the two ſubſtances. Could we find a ſubſtance that has the ſame degree of expanſion as the mean of the compounds, the thermometer would be uſeleſs, and the irregularities of expanſion of compounds, of different ſtrengths, would be too ſmall to produce any material error in the *quantum* of the revenue.

Perhaps, from this conſideration, a ball of what was formerly called *Bath-metal*, a white metal reſembling ſilver, but much harder, and not very ſubject to be corroded by ſpirit, would be the beſt material; its ſolid expanſion being about half that of Proof-ſpirit: in this caſe, the relative expanſion between ſpirit and this metal becomes only about half of that between ſpirit and glaſs; conſequently any error in aſcertaining the temperature of the fluid produces only half the error in the ſpecific gravity.

The fourth Part relates to the means of obtaining the proportional quantity of ſpirit of a given ſpecific gravity, contained in the compound now called *Proof*, which is ſtated to weigh 7℔ 12℥ *per* gallon, at the temperature of 55 degrees.

Notwithſtanding it is more than twenty years that this term of *Proof* has been eſtabliſhed, yet the proportion of ſpirit in the compound that fulfils the above conditions, has never yet been aſcertained. Hydrometers, by different makers, differ in fixing this point, I am informed, more than $7\frac{1}{2}$ *per cent.* and Government, to avoid diſputes, have been under the neceſſity of paſſing an Act to conſtitute *Clark*'s Hydrometer (for a ſhort time) the only legal one; though it is, in all probability, as vague as any of the others, particularly in compounds conſiderably higher than *Proof*.

But if proper means are uſed, this term may be fixed with as much preciſion as any other: I have not the leaſt doubt, but by the method I am about to deſcribe, we ſhall be able to obtain the value of this term to within $\frac{1}{10000}$ part of the whole.

The obſtacle to aſcertaining this term hitherto, ariſes from a difficulty of obtaining *practically* the exact capacity of our gallon-meaſure: it is indeed, ſtated to contain 231 cubic inches; yet, notwithſtanding the great pains taken by a committee, appointed by the Houſe of Commons about the year 1758, for that purpoſe, aſſiſted by ſeveral ingenious mechanics, this point was left undetermined. The method they uſed was by making *hollow cubes* of different dimenſions, from one inch upwards, which were executed with great care by the late Mr. *J. Bird*; and are now, I am informed, in the repoſitory of the Houſe of Commons; but whoever conſiders the difficulty of making an exact cube, and that of aſcertaining the inſide caliber with preciſion, muſt be ſenſible that no great reliance can be had on the exactneſs of a gallon meaſure obtained by this method.

The moſt ſimple geometrical figure, to execute with accuracy, ſeems to be a *cylinder*. By means of a tool, in uſe in my work-ſhop, a cylinder can be made, and afterwards meaſured, to the exactneſs of the $\frac{1}{1000}$ part of an inch, without much trouble: we have therefore, only to make a cylinder of braſs or other metal, of about ſix or eight inches in diameter, and about the ſame length (braſs, indeed, will be preferable to any other, on account of its expanſion being the ſame as our meaſures of inches, which are uſually made of that ſubſtance); its weight ſuch as will juſt make it ſink in water; and, having carefully determined its dimenſions in inches and decimals, by means of a very exact balance, we have only to weigh this cylinder very carefully in air, and again in diſtilled water, by which means we obtain the weight of a quantity of water, equal to the ſolid contents of the cylinder: then by a ſimple proportion, *as the ſolid contents of the cylinder in inches, is to its weight of water, ſo is* 231 *inches to the weight of a gallon of the ſame fluid.*

Having thus obtained the weight of a gallon of water; to make the reſult of uſe, we have only to make a braſs veſſel of any convenient form, having a ſmall neck, and to adjuſt it ſo, that when filled with diſtilled water, its contents may be the weight of a gallon, as before determined, at the temperature of 55 degrees: but the beſt means of determining when the veſſel is full, may be by pouring in water, till the ſurface thereof, from its own attraction, riſes above the neck of the veſſel; then laying a flat piece of glaſs on the ſurface of the water, it will, by its weight, preſs off that part of the fluid that roſe above the neck.

Thus we have a practical method of obtaining the exact quantity of a gallon meaſure; after which it will not be difficult to determine the proportion of ſpirit in a compound, that when the gallon meaſure is filled, its contents may weigh exactly 7℔ 12℥, at the given temperature: this can be obtained without an error exceeding the twenty thouſandth part of the whole. Hence we may get a permanent meaſure of capacity; and the ſame method is applicable to the eſtabliſhing meaſures of weight, by determining the proportion of the weight of a cubic inch, &c. of water, to thoſe of our pounds, ounces, &c. conſequently, ſo long as our meaſures of inches remain the ſame, ſo long will our meaſures both of weight and capacity.

LET us now compare the method I have here related, with that deſcribed for the ſame purpoſe in the *Philoſophical Tranſactions.* They adopted a method of proportioning the quantities of ſpirit and of water by weight; and added diſtilled water in the proportion of 5, 10, 15, &c. grains to every 100 grains of ſpirit; ſo that the mixtures in their experiments are expreſſed by vulgar fractions, in an harmonic progreſſion, as $\frac{100}{105}$, $\frac{100}{110}$, $\frac{100}{115}$, &c. the numerators denoting the weights of the ſpirit, and the denominators thoſe of the compound. On the contrary, my experiments are taken in centeſimal parts of the compound by meaſure, as $\frac{95}{100}$, $\frac{90}{100}$, $\frac{85}{100}$, &c. or 95, 90, 85, &c. *per cent.* of the volume.

Now every tranſaction relative to the ſale, or to the duty on ſpirituous liquors, being regulated by meaſure and not by weight, it is evident, that before any of their reſults can be of uſe, thoſe proportions by weight muſt be reduced to their equivalents in meaſure, the effects of the concentration muſt be computed, &c. &c. yet after all, we cannot by any computation whatever obtain from thoſe experiments the ſpecific gravity of 95 *per cent.* of 90 *per cent.* of 85 *per cent.* &c. without having recourſe to approximation, which ought never to be done but when it is not poſſible to obtain direct reſults. On the contrary, by the method I have deſcribed, we have the mixtures alluded to by very eaſy experiments, without any computation.

Again, the method they have purſued for obtaining the ſpecific gravities of their different compounds, ſeems liable to many objections; and that of determining the effect of heat, is both tedious and unſatisfactory. It is deſcribed after this manner: "They have a bottle nearly ſpherical, of about 2.8 inches diameter, its neck formed of a portion of a barometer tube, about 1½ inches long; it was perfectly cylindrical, and about .25 of an inch in bore; and on its outſide, very near the middle of its length, a fine circle or ring was cut round it, as the mark to which it was to be filled with the liquor. The ſpecific gravity of the compound at the different temperatures was taken by means of this bottle; the liquor to be tried was firſt brought nearly to the required degree of temperature; the bottle was then filled with it up to the beginning of the neck only, that there might be room for ſhaking it: a very fine and ſenſible thermometer was then paſſed through the neck of the bottle into the contained liquor, which ſhewed whether it was above or below the intended temperature. In the former caſe, the bottle was brought into colder air, or even plunged in cold water; the thermometer, in the mean time, being frequently put into the contained liquor, till it was found to ſink to the right point. In like manner when the liquor was too cold, the bottle was brought into warmer air, immerſed in warm water, or more commonly held between the hands, till, upon repeated trials with the thermometer, the juſt temperature was found. It will be underſtood, that during the courſe of this heating or cooling, the bottle was very frequently ſhaken between each immerſion of the thermometer, and the top of the neck was kept covered, either with the finger, or a ſilver cap made on purpoſe, as conſtantly as poſſible."

By this method of determining ſpecific gravities, and the effect of heat on the different compounds, we are ſubject to much loſs of time, and to the difficulty of bringing every part of the fluid in the bottle to the ſame required point of temperature; this is not eaſily done, particularly when the difference between the temperature of the liquor, and of the open air, is conſiderable; we are told it is done by ſhaking the bottle with its contents when within leſs than $\frac{1}{100}$ part of being full; but, on the leaſt reflection every one will allow, that in a ſpherical bottle, under theſe circumſtances, it will not be eaſy to mix the fluid by ſhaking it. We are alſo told, that they obtained the degree of temperature of the fluid by immerſing a thermometer from time to time in the bottle that contained it; now thoſe converſant in thermometrical experiments, are ſenſible, how long a time a thermometer muſt be immerſed in any fluid, before we can be certain of its having acquired the ſame temperature, even ſo near as half a degree; nor can we ever be certain, till we ſee the mercury in the thermometer move in a contrary direction to that it did when firſt immerſed in the fluid; that is to ſay, ſuppoſing the temperature of the fluid 80, and the thermometer when immerſed at 60, we cannot be certain the thermometer has the ſame heat as the fluid, till after riſing to 80, it begins to deſcend again by cooling with it: this will give us ſome idea of the time and trouble to bring their compound to a required degree of temperature, I might almoſt ſay the impoſſibility, except the thermometer remains conſtantly immerſed in it. Moreover, though their experiments are only to every fifth degree of temperature, yet each fluid is ſubject to the operation of weighing it at leaſt forty-five times; judge then what muſt be the effect on the ſtrength of the ſpirit by the evaporation of the finer parts thereof during their operations, particularly when the fluid is conſiderably hotter than the atmoſphere: and if we conſider the effect of the ſilver cap, at intervals looſely dropped on the neck of the bottle, its different conducting power will not be unfavourable to evaporation.

Nor are we leſs ſubject to erroneous reſults, when the temperature of the compound approaches towards 30 degrees, and the temperature of the air perhaps 50 or 60. Notwithſtanding the greateſt care in wiping the bottle, it will be impoſſible to prevent moiſture from condenſing on the outſide of it, which muſt obviouſly increaſe its weight.

In my experiments it is evident, that I have no occaſion to weigh each compound more than once, which being done at, or very near, the temperature of the room, I have nothing to fear from any difference of temperature in the different parts of the fluid; beſides the temperature may be determined with the greateſt accuracy, becauſe the thermometer conſtantly remains in the fluid: nor can there be any ſenſible evaporation during this ſingle experiment, the ſurface being conſtantly covered by a plate of glaſs in immediate contact with the fluid. Moreover, there is little propenſity to evaporation, when the temperature of the fluid is the ſame with that of the ſurrounding atmoſphere. Nor is it material, whether or no the temperature of the different fluids, when their ſpecific gravities are determined be the ſame, for having the temperature at the time of the experiment, and the rate of expanſion, we may eaſily reduce the different ſpecific gravities to the ſame degree.

From what has been mentioned, we ſee the impropriety of determining the effect of heat on the compound by weighing it. With my inſtrument we have nothing to fear on this head; for after the proper quantity of a compound is poured into it, the end of the tube may be hermetically ſealed till the experiments are ſatisfactory.

But the greateſt advantage ariſing from the method I have related, beſides its accuracy, is the comparative ſhortneſs of time requiſite for making a moſt complete ſet of experiments, to aſcertain the ſtrength of compounds, or the quantity of ſpirit contained therein, from 5 *per cent.* of ſpirit up to 100, and that to every ſingle degree of temperature on Fahrenheit's thermometer, this may be performed in a few days by any one not much in the habit of making experiments. On the contrary, though the experiments deſcribed in the *Phil. Tranſact.* go no lower than *Proof*, and the expanſion determined only to every five degrees of the thermometer, yet we are told, that they have had occaſion for more than *one thouſand* weighings.

It was reaſonable to expect we ſhould have been favoured with ſome rule, for reducing the proportion of ſpirit in their experiments by weight, to thoſe of meaſure: But as that has been omitted, I ſhall, for the uſe of thoſe not very converſant in ſuch matters, give an example of the computation requiſite for that purpoſe; this ſhall be to compute the number of gallons of ſpirit contained in each 100 of the compound, for the proportion of 100 grains of ſpirit to 35 of water.

Suppoſe the ſpecific gravity of water 1, and that of ſpirit .825, the magnitude or volume of a quantity of ſpirit, weighing 100 grains, will be 121,2121, &c. which, added to 35, the volume of water, the proportion in that experiment will be expreſſed by this fraction $\frac{121,2121,\ \&c.}{156,2121,\ \&c.}$ which reduced will ſhew, that in every 100 galons of the compound there are 77,5945 gallons of ſpirit; and this reſult would be true if the mixture was mechanical, that is to ſay, if there was no penetration: but as the two ſubſtances penetrate each other, we muſt compute the effect ariſing from that circumſtance: previous to this, it will be neceſſary to compute what would have been the ſpecific gravity of the compound, had there been no penetration; this will be found by dividing 135, the total weight of the two ſubſtances, by 156.2121, their magnitude; the quotient, ,8642, would have been the true ſpecific gravity, had there been no penetration.

But the diminution of the volume by penetration, being inverſely, as the ſpecific gravity by computation, is to the ſpecific gravity determined by experiment, we ſhall have the following proportion, namely, as .8642, the computed ſpecific gravity, is to ,88181, the reſult of the experiment given in their table, ſo is unity to ,98004, the quantity to which the volume is diminiſhed, by the penetration. Laſtly, as .98004 is to 1, ſo is 77.5945 to 79.1748, &c.; that is to ſay, each 100 gallons of a compound of the ſpecific gravity of ,88181, will contain 79.1748 gallons of ſpirit, of the ſpecific gravity of ,825, at a certain temperature.

Thus, after a long computation, we have the ſpecific gravity of a compound, containing 79.1748 gallons, or *per cent.* of ſpirit. Now, it is the ſpecific gravity of centeſimal parts of the compound we are in ſearch of: but how to obtain, from thoſe reſults, the ſpecific gravity of a compound, containing 80 *per cent.* of ſpirit, I am at a loſs to determine.

From what has been ſaid in the preceding pages, it may be concluded, that I conſider the preſent mode of aſcertaining the term of *Proof*, as preferable to any other. This is not the caſe. But to retain the preſent value of *Proof*, will, no doubt, have many advantages: it will prevent that confuſion which always happens in commerce, when any change of the value, or denomination, of merchandiſe takes place. I would therefore propoſe to aſcertain what is the ſpecific gravity of the *Proof* by *Clark's Hydrometer*, or as it was fixed (by the weight *per* gallon), and make that ſpecific gravity the term: by thus retaining the preſent value of Proof, the *Bubble* ſtill remains a ſort of criterion when Hydrometers are not at hand, and Proof being pretty near a mean of the different ſtrengths at which ſpirituous liquors are imported, we facilitate the computation for reducing the duty on ſpirits of a different ſtrength, to that value: our multiplier could rarely be greater than 11, becauſe ſpirituous liquors from any place, except the Weſt Indies, are not permitted to be imported ſtronger than 11 *per cent.* above the preſent *Proof:* whereas, if the term of Proof, on which the duty is aſcertained, was taken at the ſpecific gravity of .825, we ſhould have a conſiderable reduction; our multiplier would ſeldom be leſs than 72, and often above 90.

On the thermometer to be uſed with the balance hydrometer, beſides Fahrenheit's ſcale, it might be of uſe to have ſcales for the effect of heat on compounds of different ſpecific gravities, or different *per cents.* of ſpirits, denoting what reduction or augmentation is to be made in *per cents.* of the duty at Proof. Or the ſame thing may be done, by having the degree of heat on Fahrenheit's ſcale, and applying it to a table computed for that purpoſe. When government ſhall have fixed the value of *Proof,* I intend to conſtruct a ſmall table, on principles very different from what has been done hitherto, whereby the effect of heat on a compound may be had in *per cents.* or even in fractions of *per cents.* of the duty at proof, by ſimple inſpection.

To illuſtrate what I have juſt related, concerning the advantage of adhering to the preſent value of Proof, and alſo to ſhew the ſuperiority of centeſimal proportions, I ſhall give two examples of the computation for reducing the duty on ſpirituous liquors, of any different ſtrength and temperature, to that of Proof.

RULE. By a table, or otherwiſe, compute the duty on the number of gallons at the duty *per* gall. at Proof: then take the number of *per cents.* indicated by the balance hydrometer, and alſo thoſe ſhewn by the thermometer; if the ſcales ſhew both additive or both ſubtractive, take the ſum; but if one is additive, and the other ſubtractive, take the difference: then multiply this ſum or difference by the value at proof, and the product, when two figures are cut off to the right for decimals, will be the *correction:* when the ſum is uſed, both ſcales will ſhew if this correction is to be added to, or ſubtracted from the value at Proof; but if the difference is taken, it muſt be applied as indicated by the greater of the two on its proper ſcale.

Ex. I. Suppoſe the duty on proof-ſpirit is 7*s.* *per* gall. and the quantity 120 gallons;

120 at 7*s.* — — — — £42

Strength indicated by the hydrom. 7 *per cent. above,* — — — } ſum 10

By the thermom. for temp. 3 *per cent. above,* }

4.20 the *correction*, which, *added* to £42 (both being above) ——

gives — — — — 46.20 the duty on the compound corrected for the ſtrength and temperature.

Ex. II. 120 gall. at 7*s*. — —		£ 42
By hydrom. *under proof* 7 *per cent.* By thermom. *above proof* 3 *per cent.*	diff. —	4
Correction — — —	*ſub.*	1.68
The duty corrected — — —		40.32

But, previous to any experiments on this ſubject, the term of Proof ſhould have been fixed, and the proportions in making the experiments taken in ſpirits of that degree of ſtrength. From the reſults already given in the PHIL. TRANS. we might, by computation, approximate pretty nearly what would be the ſpecific gravity of compounds centeſimally proportioned to this term, as far as the experiments are carried; but the concluſions could never be very ſatisfactory. And a repetition of experiments on a leſs objectionable plan, and equally accurate, would only be the work of a few days; or a greater expence, excluſive of ſpirits, than 5 or 10 pounds.

Yet, under certain circumſtances, the denſity of ſpirituous liquors is no criterion of the ſtrength; for it is well known that frauds have been committed, by diſſolving ſome ſubſtances in ſpirituous liquors, by which the ſpecific gravity has been increaſed, without ſenſibly diminiſhing the ſtrength; thereby eluding the teſt of the common hydrometer. This induced me to make the following experiments, not with any great degree of accuracy, but merely as an example of a farther uſe to which the balance hydrometer is applicable.

I took ſome brandy, ſuch as is uſually ſold at the wine-vaults; its ſpecific gravity was 936, at 60 degrees of temperature; to this I added ſugar, not ſo much I believe, as the brandy would diſſolve; after ſhaking the ſolution well, it was left about 48 hours in a cloſe ſtopped phial, and it appearing tolerably clear, I aſcertained its ſpecific gravity, which was found to be 976, in the ſame temperature as before, or 60 degrees. To try how far we might detect ſolutions of this ſort, I made a light copper diſh, ſuch as repreſented by *fig.* 6. which might be ſuſpended to the hook of the balance, in place of the horſe-hair and glaſs bulb, by means of a braſs wire; one end of which was fixed in the middle of the diſh, the other terminated in an hook, whereby to ſuſpend it to the balance; the weight of the diſh and wire was ſuch, that, when ſuſpended on the balance, and the ſlider ſet to 1000, it would be in equilibrium; I then ſet the ſlider to 800, and put as much of the ſolution into the diſh as reſtored the equilibrium; this quantity I ſhall call 200 parts.

I then unhooked the diſh, and putting it over the fire, evaporated the ſpirit, and the ſugar remained in the bottom of the diſh, which being again ſuſpended on the balance, and the equilibrium reſtored, by moving the ſlider along the beam, the index then ſhewed 979.7; therefore the ſolution contained $\frac{20.3}{200}$ parts of its weight of ſugar. After this, I took 200 parts of the brandy (without ſugar), and evaporating it as before, there remained a little black ſubſtance, but it did not weigh more than $\frac{1}{1000}$ part of the whole.

Next, I took a quantity of rum, of the ſame ſpecific gravity, or 936, to which ſugar being added, and the ſolution remaining about the ſame time as the preceding, I aſcertained its ſpecific gravity, which was 964; the rum (without ſugar) was then treated in the ſame manner as the brandy, nor did its *reſiduum* exceed the $\frac{1}{1000}$ part, as before.

Theſe experiments ſhew the poſſibility of defrauding the revenue by ſuch ſolutions. Perhaps ſubſtances may be found that would increaſe the denſity of ſpirits much more than ſugar, and alſo methods of precipitating the ſubſtance without diſtillation; but not being a chemiſt, I have no knowledge in theſe matters. Was a revenue officer poſſeſſed of an inſtrument whereby ſuch frauds could be detected, it might prevent them from being attempted; and in caſe of ſuſpicion, the officer could, in leſs than ten minutes, aſcertain the proportion of the *reſiduum* to leſs than $\frac{1}{1000}$ part of the whole.

Thus far my object has been preciſion. But the balance hydrometer being a new inſtrument, and the revenue officers not in the habit of uſing them, ſpecific gravities determined thereby, may ſeem at firſt, to require more time than in uſing the common hydrometer; but I am confident, that after an hour's practice, an officer will be able to aſcertain the ſpecific gravity of any ſpirituous liquor in the ſpace of two minutes;

and, if we conſider the changing of the weights, &c. I much doubt, whether it could be done in leſs time with the common hydrometer; yet even the *whole* of the time would be amply compenſated by the accuracy of the determinations.

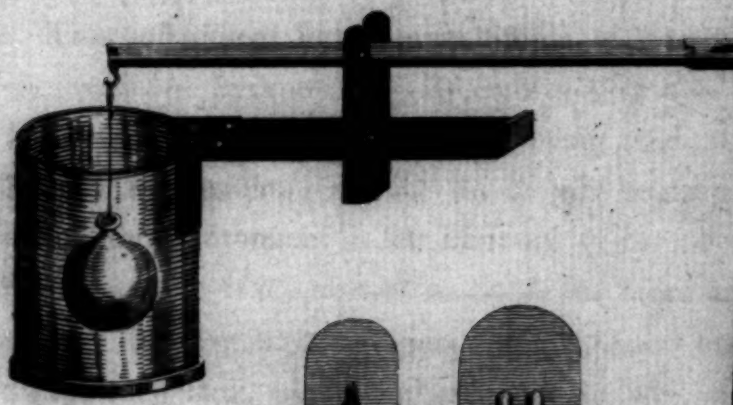
But if we ſuppoſe a leſs accurate method to be practiſed, we may be certain, that whatever are the errors, they will infallibly be againſt the revenue. So ſoon as theſe matters are ſettled, merchants will immediately furniſh themſelves with proper inſtruments, whereby to aſcertain the duty on their ſpirits, with the greateſt preciſion. Whenever errors militate againſt their intereſt, they will not fail to complain; and vague determinations will always be unſatisfactory, except to thoſe who profit by them. Moreover, a moment's reflection will convince us, that the aggregate of ſmall errors in the duty, which ſingly may appear trifles, will be a very conſiderable ſum on the whole of this branch of the revenue.

However, ſhould the common hydrometers be adhered to, becauſe the revenue officers are accuſtomed to uſe them, I have conſtructed one that ſeems to have many advantages over thoſe I have yet ſeen. It conſiſts of a glaſs tube, about four *Fig. 7* inches long, and ¾ inch diameter; the upper end of this tube terminates in a ſmaller one, in which is a ſlip of ivory; on this ivory is a ſcale that contains 100 diviſions, the middle one being the *zero*; the other diviſions above and below, are numbered 10, 20, &c. to 50. The middle one, or *zero*, expreſſes the ſtrength or ſpecific gravity of *proof-ſpirit*, at the temperature of 60 degrees; the diviſions above the *zero* ſhewing how much the ſpirit is ſtronger than *Proof*, in centeſimal parts; thoſe below the *zero*, in like centeſimal parts, how much the ſpirit is weaker.

The larger, or lower tube, contains a thermometer, having Fahrenheit's ſcale graduated on one ſide, and on the other a ſcale, ſhewing how much the ſpirit appears ſtronger or weaker than at the temperature of 60 degrees, in centeſimal parts of the value at *Proof:* the *zero* of this ſcale is oppoſite the 60th on Fahrenheit, and the diviſions above and below that point, are numbered 10, 20, &c. Thoſe above the *zero* ſhewing the number of centeſimals to be ſubtracted to correct the reſults, by the hydrometer, to the temperature of 60 degrees: thoſe below, the number of centeſimals to be added.

The application of this hydrometer is as follows: Immerge it in the ſpirituous liquor, of which the value is to be determined, and obſerve to what diviſion on the ſmall ivory ſcale the hydrometer ſinks, that number will expreſs, in centeſimals, how much the ſpirit is above, or below *Proof* if the temperature was at 60 degrees on Fahrenheit's ſcale, or at the *zero* on the ſcale of correction on the thermometer; then taking out the hydrometer, examine at what point the mercury in the thermometer ſtands on the ſcale of correction, that number will expreſs, in centeſimal parts of the value at *Proof*, the

Fig. 5.



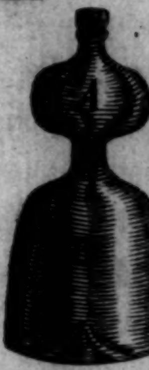


Fig. 1.

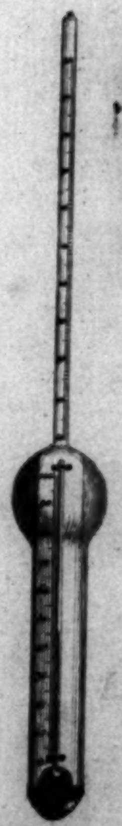
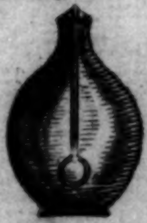


Fig. 7.

Fig. 3.



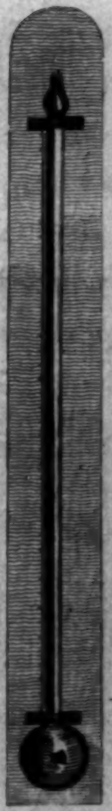


Fig. 2.

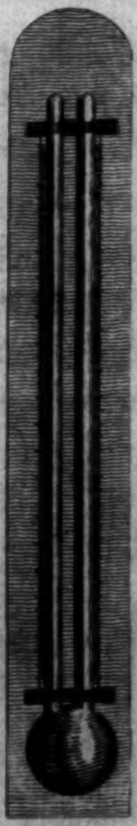


Fig. 4.

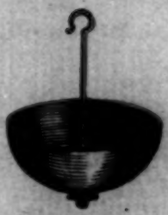


Fig. 6.

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the correction for reducing the reſult by the hydrometer, to the temperature of 60 degrees.

The computations will be ſimilar to thoſe given at *pag.* 27, 28.

This inſtrument ſeems more ſimple and convenient than the common hydrometer. By conſtructing the hydrometer and thermometer in one, we avoid being troubled with two ſeparate inſtruments; and the lower tube being nearly cylindrical, the hydrometer is leſs impeded in its motion through the fluid, than if it had been made in the common form like a ball. The ſcales being ivory, the diviſions become more conſpicuous than on any other material: and, without the trouble of weights, we have a ſcale that exceeds the limits at which ſpirits are permitted to be imported. To this may be added, the conveniency of centeſimal graduations. Yet after all, I cannot help thinking the balance hydrometer the beſt inſtrument, but in that it might be more convenient to have a glaſs cylinder inſtead of the bulb, and the thermometer within it.

FINIS.

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